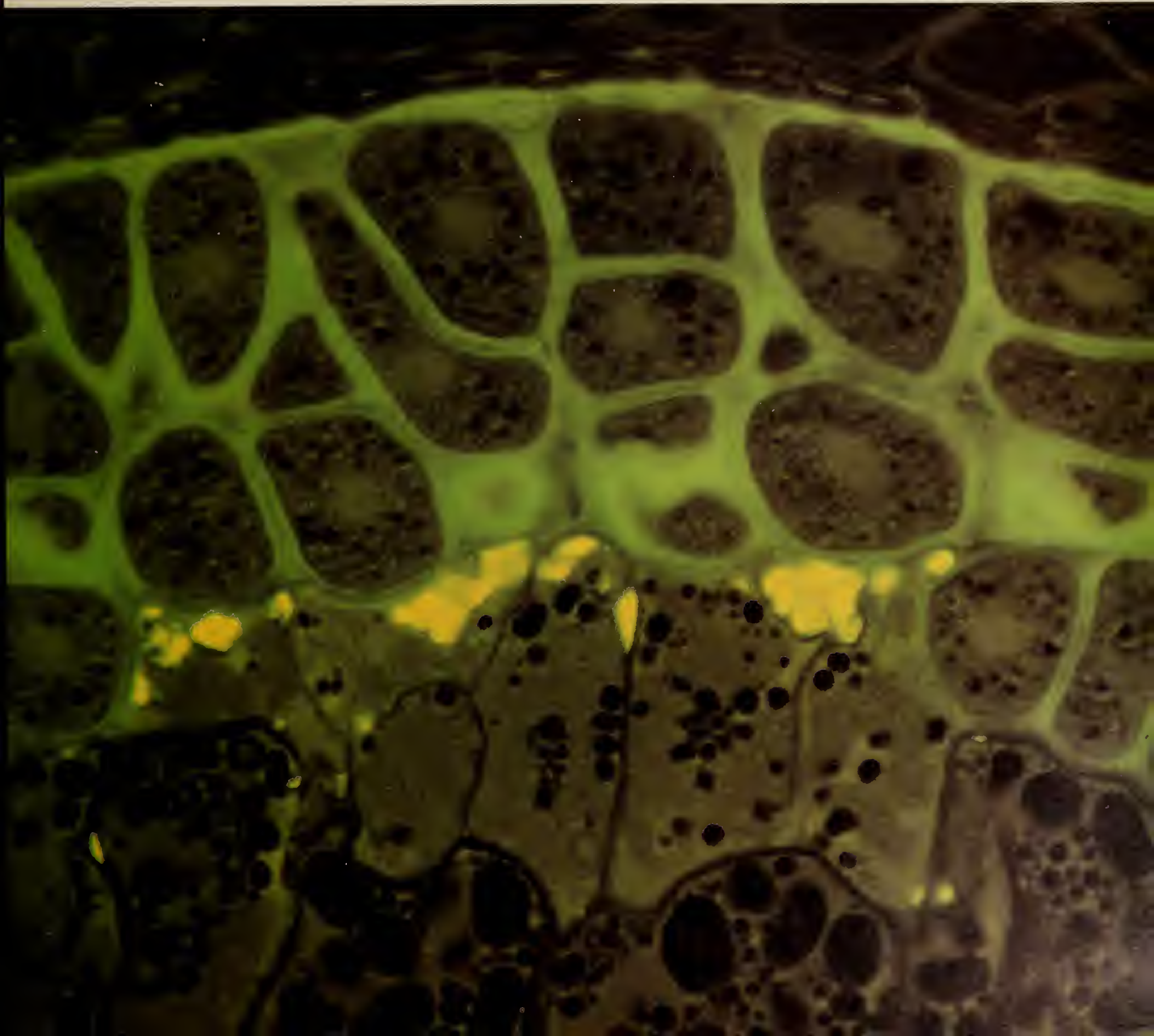
A fluorescence micrograph of barley endosperm showing yellow fluorescence after niline Blue staining. See story on page 16.

Micrographe de la fluorescence de l'endosperme de l'orge indiquant la fluorescence jaune après coloration à l'aniline bleue. Voir à la page 16.

CANADA AGRICULTURE



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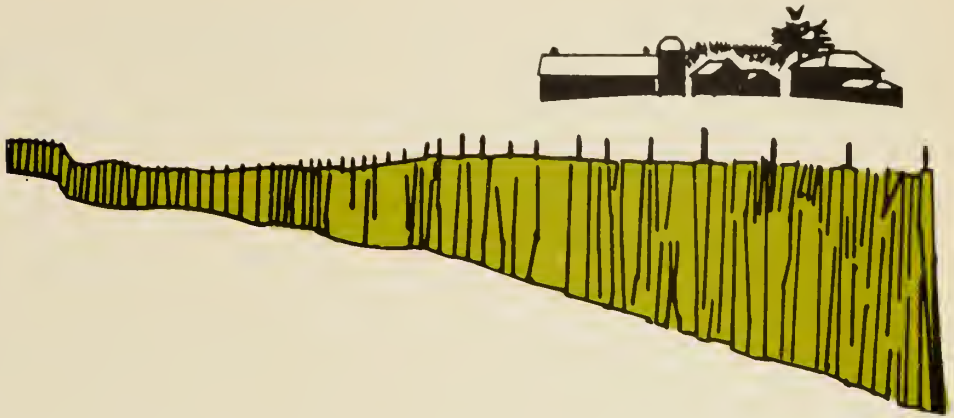
Agriculture Canada

OVERWINTERING INJURY TO WINTER CEREALS IN EASTERN CANADA

M. K. POMEROY and
C. J. ANDREWS



Les basses températures ne sont pas les seules responsables des dommages subis par les céréales d'hiver dans l'Est du Canada. Le compactage de la neige à la surface du sol et la formation de croûtes de glace au-dessus des végétaux jouent également un rôle important.

Climatic conditions make it difficult to develop winter cereals capable of survival and satisfactory yield potential in Eastern Canada.

Some years, autumn temperatures may be unusually low and permanent snow cover may not occur until January, resulting in low air and soil temperatures and widespread ground frost. Other years, early snowfalls prevent freezing of the soil surface, and soil temperature remains around 0°C throughout the winter. Mid-winter thaws and rain are also common in eastern Ontario.

There are several causes of injury to winter cereals in Eastern Canada. Plants can be damaged or killed by low air or soil temperatures. Smothering may also occur due to accumulation of packed snow and ice at the soil surface (Fig. 1). Autumn or spring flooding, and attack by fungal pathogens commonly known as snow molds, are other possible sources of damage to overwintering cereal crops.

Research over the past few years at the Chemistry and Biology Research Institute, Ottawa, has been directed towards examining this problem. One objective of these studies is to determine the major cause of overwintering injury to winter wheat in eastern Ontario. In addition, biochemical investigations are being conducted to determine why some wheat cultivars are better able to survive these winters than other cultivars.

In field experiments, we simulated a number of natural environmental conditions. These studies involved sampling plots throughout autumn and winter to examine the effects on winter survival of soil-moisture content during autumn hardening, snow accumulation, mid-winter thaws, and spring frosts. Various winter conditions were simulated by removing snow, placing snow fences to accumulate snow on plots, and adding water to plots at appropriate times during fall and winter. These techniques made it possible during the course of an individual season to simulate climatic conditions which occur naturally only every few years (Fig. 2).

These investigations show that low temperature alone is often not the cause of winter injury to cereals in Eastern Canada, since the soil temperature does not normally drop below the killing point in autumn, and rises to −1 to −3°C under the gradually accumulating snow cover of early winter. This situation contrasts sharply with much of the Canadian prairies where snow cover is often minimal and soil and air temperatures may be reduced below that required to kill many winter cereals. Our observations show that while the degree of tolerance to low temperature is an important factor in determining winter survival of cereals in Eastern Ontario, compaction of snow at the soil surface and the formation of ice sheets over the plants also play an important role (Fig. 3). Consequently, the selection of winter-cereal cultivars suitable for eastern Ontario must take all these factors into consideration. Currently, winter-cereal lines are being tested for resistance to freez-

Figure 1. Naturally occurring ice sheet over a winter wheat field plot.

Drs Pomeroy and Andrews are members of Agriculture Canada's Chemistry and Biology Research Institute, Ottawa.

ing injury and tolerance to ice encasement.

Controlled-environment studies in low-temperature growth facilities confirm that ice encasement reduces the survival of winter-cereal seedlings and increases their susceptibility to damage from subsequent frosts. In experiments, cold-hardened winter-cereal seedlings were encased in ice at $-1°C$ for an increasing period of time. After thawing, the plants were rated for survival and cold hardiness. Biochemical analyses were carried out to examine the effect of ice encasement on metabolic processes of the plants. The accumulation of several products of anaerobic respiration, including ethanol, lactic acid, and carbon dioxide, occurred under these conditions. If these chemicals are added to seedlings, they suffer damage very similar to that which occurs during icing. The results of these studies indicate that the major cause of damage during ice encasement is the accumulation of carbon dioxide and ethanol to toxic levels in the plant tissues.

The Winter Hardiness Group is also carrying out research on cold hardening and freezing injury in cereals. Changes in the physical and chemical properties of plant cells during acclimation to low temperature and injury due to freezing are being investigated. Recently developed techniques have greatly facilitated the isolation of various factors involved in the response of plant cells to low or freezing temperatures. The outer cell membrane is most likely to be involved in the hardening response, and has been injured directly by freezing and desiccation stresses.

A solution to the problem of expanding winter wheat production to more marginal areas with environmental extremes has not yet been attained, but the outlook for progress towards this goal is bright. Through the co-operation of plant breeders and scientists attempting to understand the causes of overwintering damage to wheat and other cereal crops, new and better methods of screening for improved cultivars are being developed. We are also gaining a better understanding of the biochemical processes involved in cold hardening and freezing injury. ■

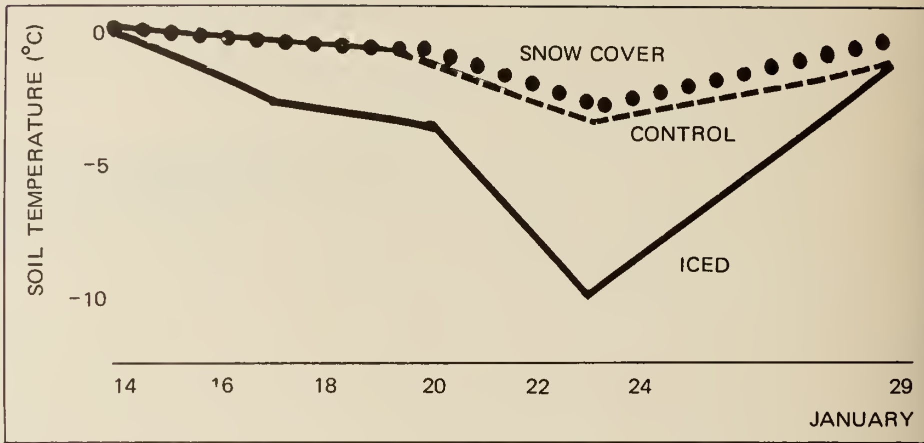


Figure 2. Soil temperatures at 1-cm depth in undisturbed control plots and artificially iced plots which were either immediately recovered with snow, or kept clear of snow for 8 days.

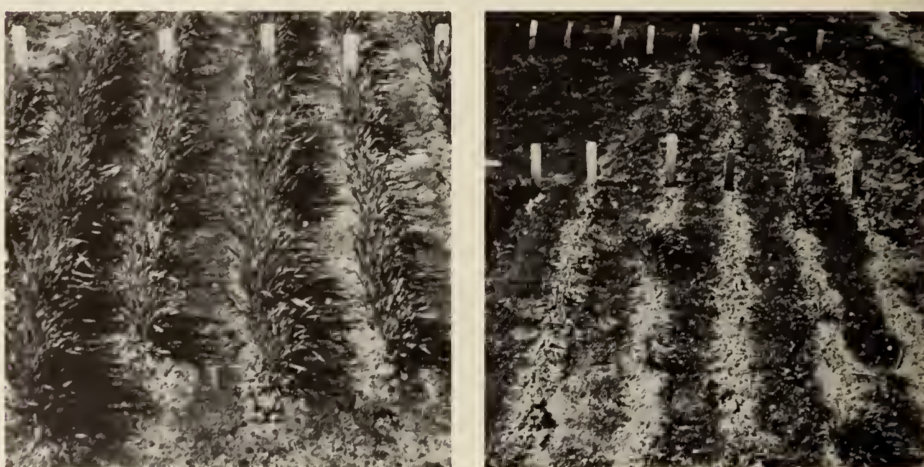


Figure 3. Spring survival of winter wheat in an untreated field plot (A), and a plot artificially encased in ice in January (B).

SEMI-DWARF BUCKWHEAT

C. G. CAMPBELL

Les variétés de sarrasin qui possèdent des gènes codant un semi-nanisme chez la plante seraient supérieures aux variétés plus hautes actuellement sur le marché. Les nouveaux cultivars devraient mieux s'adapter aux sols plus fertiles et permettre l'accroissement des emblavures actuelles.

Buckwheat in Canada had traditionally been produced on small acreages by ethnic groups for their own use. There was a gradual decline in the amount grown due mainly to competition from the cereal grains. During the past 20 years, however, interest in buckwheat as an export crop has increased. In 1978, 60 300 ha were grown, compared with 18 860 in 1960. Production in 1978 was 66 500 t with an average yield of 1.1 t/ha. The main importing country is Japan, where buckwheat is consumed in the form of noodles, a traditional dish. With continued export prospects, it is expected that production of the crop will remain fairly stable and that it will be an important special crop.

The major production area of buckwheat is in Manitoba where approximately three-quarters of the total Canadian production is grown. Most of the remainder is grown in Ontario and Quebec.

Buckwheat is a succulent broadleaf plant with large, heart-shaped leaves. It has one main stem with several branches, all of which are hollow. Buckwheat has showy white flowers in dense clusters at the end of branches or on short pedicels arising from the axils of the leaves. Because it flowers over an extended period of time (often for two months), flowers, green seed and ripe seed may all be on a plant at the same time.

Buckwheat has been grown as a "catch" crop where weeds or wet field conditions have precluded growing cereal crops. It has also been called a poor man's crop as it does well on sandy soils low in fertility. For these reasons most of its production has been on the lighter-textured soils.

The increased interest in growing buckwheat as an export crop has led to the expansion of the crop over a larger area. It is now being produced on the heavier-textured, more fertile soils and is increasingly being included in crop rotations. Many of these rotations have high rates of fertilizer application; therefore, the available nutrient content of the soil is fairly high.

These trends, combined with its indeterminate type of growth, have led to some problems with the crop. The licensed varieties of buckwheat — Mancan, Tempest and Tokyo — have averaged approximately 110 cm in height in Manitoba over the past 7 years. However, on the more fertile soils, under favorable growing conditions, plant heights of 150 cm or more have been attained. This has created problems of lodging in the crop. As the buckwheat stem is succulent and hollow, it often "crimps" when it lodges. Buckwheat does not have the ability to recover from lodging as do cereal crops. Yields in lodged fields are reduced and further losses can occur due to excessive shattering of

Figure 1. A 4-week old normal buckwheat plant on the right and a semi-dwarf plant on the left showing the shortened internodes and a more branched growth habit.

Figure 2. Mature plants of normal buckwheat on the right and semi-dwarf on the left showing the shorter, profuse branching habit of the semi-dwarf.

Dr. Campbell is a plant breeder at Agriculture Canada's Research Station, Morden, Man.

Figure 3. The shortened internode of a semi-dwarf plant on the right is almost solid compared with a hollow stem from a normal plant shown on the left.

the ripe seeds during swathing operations. The combination of lodging and profuse branching can make harvesting operations very difficult.

Finding several forms of semi-dwarf growth mutants at the Morden Research Station prompted the effort to incorporate this growth habit into commercially acceptable varieties. This is being done by backcrossing the commercial lines to the mutant to incorporate the agronomically desirable genes from these lines with those producing the semi-dwarf habit.

Two of the most promising semi-dwarf mutants shorten the first five to six internodes produced on the plant. This allows the leaf area to remain the same, and also promotes earlier initiation of side branches. The result is a sturdy, well-branched plant. The branch development appears normal and this gives rise to a plant 75 to 85 cm in height that has sufficient stem to produce a good swath. The lower internodes are almost solid and do not bend over or crimp even under adverse conditions. Preliminary studies using high fertility (180 kg of N_2 and P_2O_5 per ha) indicate that the semi-dwarfs are highly resistant to lodging and thus should be able to be grown on fertile soils. Trials are continuing to determine the effect of fertilizer on yields, the correct plant spacing and the best seeding and harvest time for these semi-dwarf types.

An added advantage of the short, almost solid main stem is its resistance to hail. The present varieties are very susceptible to hail damage as the succulent stem readily breaks off when hit. The near-solid stem, however, only bruises when struck with the same force.

If semi-dwarf buckwheats are successful, production of buckwheat in the higher rainfall areas of eastern Canada may also increase.

The buckwheat varieties possessing the semi-dwarf genes should be superior to the taller-growing varieties presently available. They should be more adaptable to more fertile soils and this should allow extension of the present growing areas. By being able to place these buckwheats in a crop rotation where better care can be taken of the crop, it is hoped that yields can also be increased. ■

CELL WALLS AND PASTURE BLOAT

R. E. HOWARTH,
B. P. GOPLEN and G. L. LEES

Une découverte récente sur le météorisme des pâturages pourrait favoriser la réduction de l'effet météorisant de la luzerne par la sélection. Il y a quelque temps, on a en effet identifié la structure de la paroi cellulaire comme principal agent du météorisme.

Alfalfa is a remarkable forage crop. It grows in nearly all the cultivated areas of the world and produces forage of a quality unsurpassed by any other crop. Yet alfalfa's potential for causing pasture bloat is a major limitation to its use in pastures, especially under extensive grazing conditions where conventional methods of prevention and treatment of pasture bloat are not practical. For this reason, research on pasture bloat has been conducted through the co-operative work of scientists at three Agriculture Canada Research Stations: Saskatoon, Kamloops and Lethbridge.

Recent progress in this research has greatly enhanced the prospects for reducing the bloat potential of

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alfalfa by plant breeding. These developments have identified the structure of the cell wall as an important factor in the occurrence of pasture bloat.

Plant cell walls provide the structural framework for plants. They completely enclose the cells which are the sites of photosynthesis, respiration and other metabolic activities. The plant cell constituents, i.e. proteins, sugars, and starch, are valuable nutrients for livestock; but the same cell constituents are the immediate culprits in causing pasture bloat.

There are several reasons for implicating the cell constituents in pasture bloat. First, they are ideal nutrients for the rumen bacteria that digest the cell constituents. In so doing, they produce a substantial volume of gas. Secondly, this gas is retained within the rumen in the form of small gas bubbles dispersed throughout the rumen fluid. The animal cannot belch the gas because it has not separated from the rumen fluid. The plant cell proteins are the "foaming agents" responsible for the retention of gas in the rumen.

In addition to providing a structural framework, plant cell walls protect the plant cells against invasion by pathogenic microorganisms. To fulfill this role, the cell wall contains complex chemical defences which may limit the penetration of the cell wall by microorganisms. This suggests some interesting questions. Do plant cell walls also act as a barrier to rumen bacteria which would, perhaps, prefer the rich nutrients inside the cell over the array of anti-microbial defences on the outside of the cell wall? Further, would variation in the degree of cell rupture by chewing when the animal first consumes the forage influence

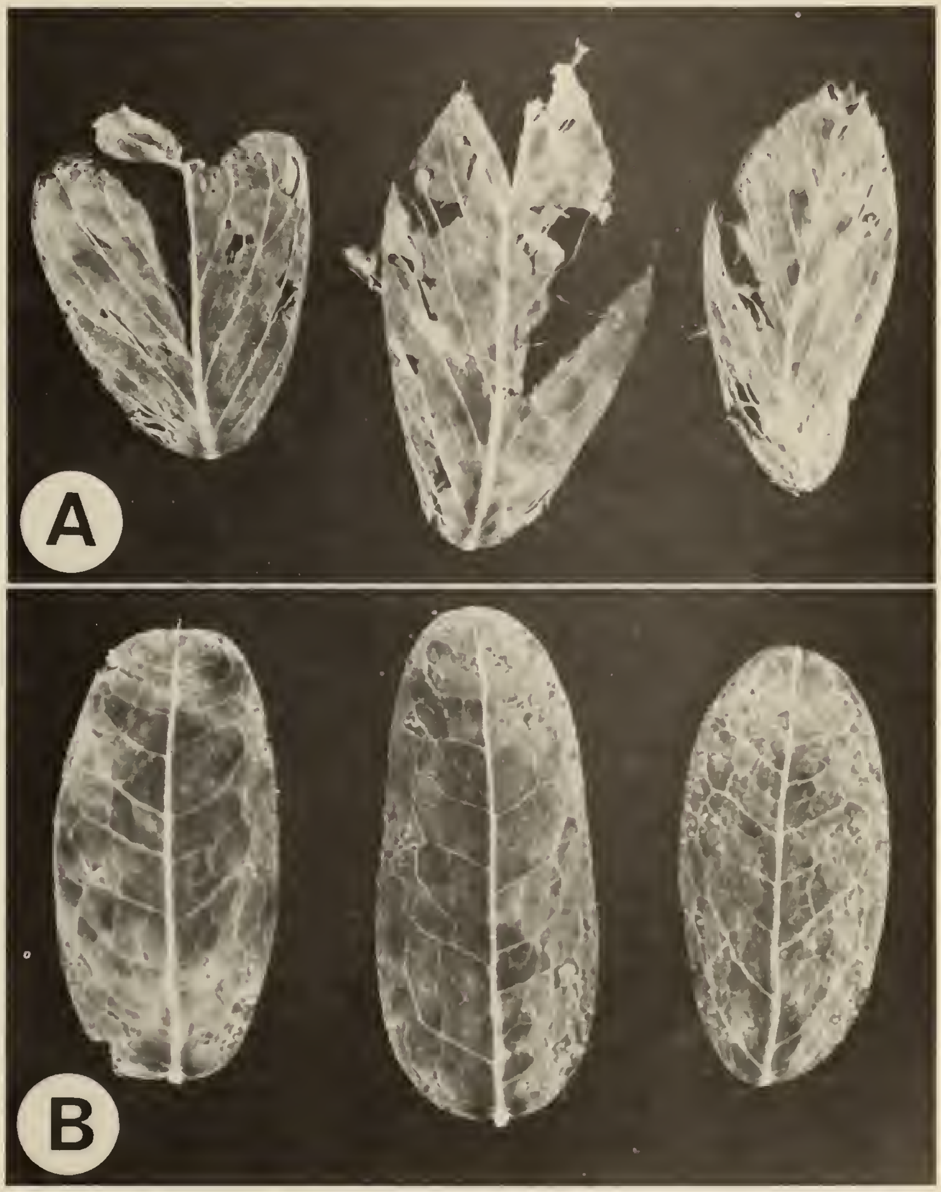

Figure 1. Greater mechanical disruption of alfalfa leaves (A) compared with cicer milkvetch (B)

the release of nutrients and foaming agents from the inside of the cell? We looked for answers to these questions by comparing the cell wall characteristics of the following bloat-safe and bloat-causing legumes.

BLOAT-SAFE AND BLOAT-CAUSING FORAGE LEGUMES

Bloat-safe	Bloat-causing
Birdsfoot trefoil	Alfalfa
Cicer milkvetch	Red clover
Sainfoin	White clover

Results were striking. Compared to bloat-safe legumes, leaves from bloat-causing legumes were more susceptible to mechanical damage as well as to digestion by rumen bacteria. Figure 1 shows alfalfa and cicer milkvetch leaves after vigorous shaking with water and glass beads. The greater mechanical damage to alfalfa leaves is readily apparent. Figure 2 illustrates differences in rates of digestion by rumen bacteria. These leaves were incubated with rumen bacteria for 18 hours. There was a significant dry-matter loss from the alfalfa leaves and areas of microbial digestion can be seen. In contrast, the sainfoin leaves showed no visual sign of digestion and there was no detectable dry-weight loss. These and other research results have given strong support to the idea that leaf-cell rupture is an important event in pasture bloat because it is a prerequisite to release of the nutrients and foaming agents from the inside of the cell. Cell rupture may occur either during chewing or by microbial digestion of the cell wall.

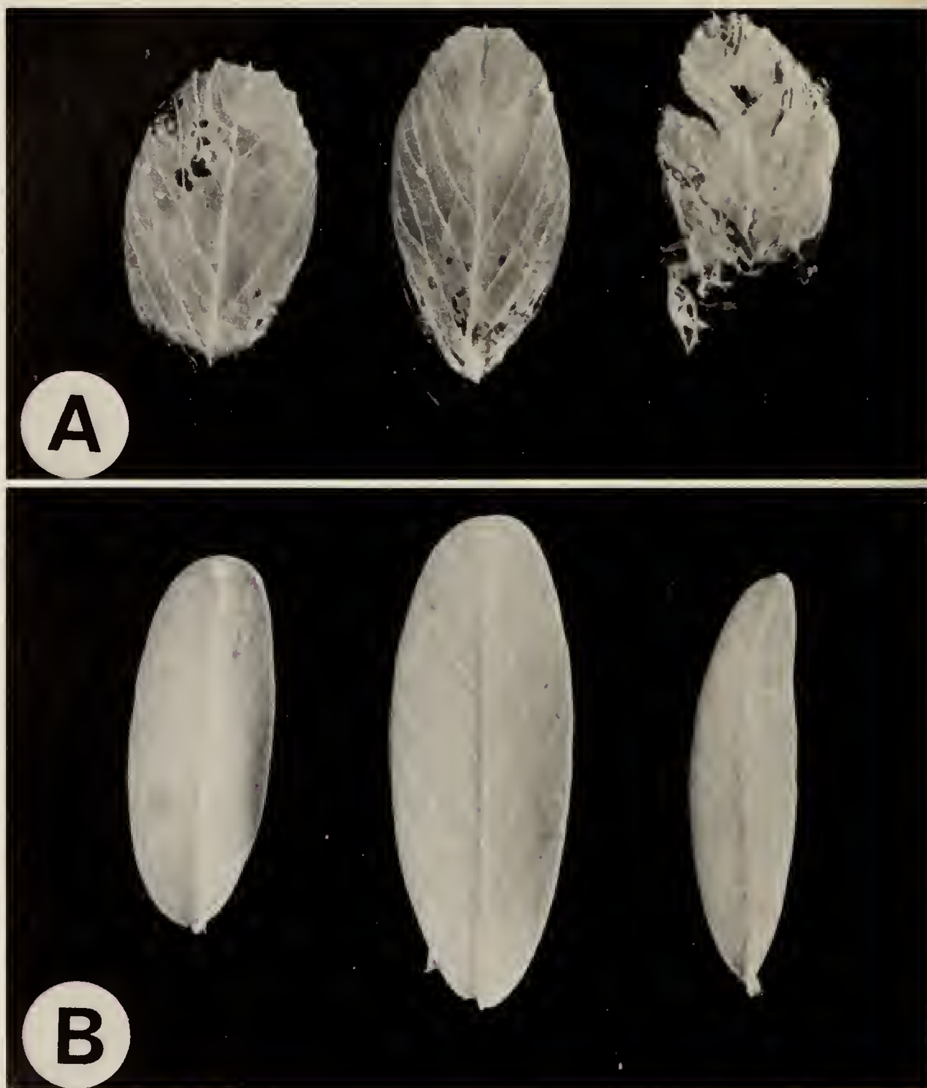

Figure 2. Greater digestion of alfalfa leaves (A) by rumen bacteria compared with sainfoin (B).

When fresh alfalfa is ingested by cattle or sheep, the onset of digestion occurs very quickly with the peak period of digestion about 2 hours after feeding. Bloat typically occurs during the same period. In contrast, with bloat-safe legumes the onset of digestion is slower and the post-feeding peak of digestive activity is less pronounced. Nevertheless, the overall digestibility of most bloat-safe legumes does not differ from that of bloat-causing legumes. Alfalfa causes pasture bloat because it is digested too rapidly, especially during the first few hours after feeding.

In addition to explaining the differences between bloat-safe and

bloat-causing legumes, the cell-rupture theory may explain other observations on pasture bloat. For example, it is frequently observed that bloat occurs on lush, rapidly growing pasture. Under these conditions the plant cell walls are still expanding. They are thin and quite susceptible to mechanical damage and microbial digestion. Rainfall or heavy dew may cause bloat by making plant cells turgid and more susceptible to rupture by crushing.

The cell-rupture theory suggests ways to reduce the bloat potential of alfalfa, hopefully even to develop a bloat-safe variety. Plant breeders should be able to slow down the initial rate of digestion of fresh alfalfa by selecting plants with cell walls with greater resistance to mechanical crushing and to microbial digestion.

Can we identify and select individual alfalfa plants with these characteristics? We have shown that this can be done, but with analytical methods that are too slow for practical plant-breeding programs. Our immediate objective is to devise and test simpler, faster methods for estimating initial rates of microbial digestion and to find more alfalfa plants with the slow digestion characteristics. These plants must then be assembled into new strains that can be directly tested for bloat potentials.

An alternative approach to breeding a bloat-safe legume deals with the proteinaceous foaming agents rather than the cell walls. The foaminess of proteins is neutralized in the presence of tannins, another group of plant constituents. Sainfoin contains a substantial amount of tannins, a fact that probably contributes to its bloat-safe characteristic. We, and others, have searched for alfalfa plants that contain tannins, but so far not a single plant has been found. We are continuing our search in mutagen-treated plants because if an alfalfa mutant which produces tannins could be found, this characteristic could be quickly used in breeding a bloat-safe alfalfa variety.

Although the different cell-wall characteristics of bloat-causing and bloat-safe legumes are quite striking, the reasons for these differences are still obscure. The major chemical constituents of cell walls are cellulose, hemicellulose, pectin, protein and ash (especially calcium and silica) .We are looking for differences in these chemical constituents, but to date we have not found any notable differences between the bloat-causing and bloat-safe groups of legumes. It is clear that the physical characteristics of plant cell walls vary widely among forage species and that each species has its own unique characteristics. These physical properties of cell walls are of interest, not only to pasture bloat, but also to other quality characteristics of forages, especially voluntary intake and nutritive value of low-quality forages. They are low-quality, in part, because of slow physical breakdown of the cell-wall fibers into particles small enough to pass out of the rumen. Such breakdown occurs by microbial digestion, cud-chewing, and mixing of rumen contents.

The attractive features of the cell-rupture theory of pasture bloat are that it has provided a new approach to our understanding of this complex disease and that it suggests new approaches to the development of bloat-safe legumes without markedly altering their valuable nutritive properties. There is now increasing interest in other countries in removing the bloat potential from alfalfa and red clover. We are at the stage where this is a realistic goal for plant breeders.

We foresee rapid acceptance and extensive use of a bloat-safe alfalfa variety in Western Canada where beef cattle are grazed over large acreages of dryland pastures. Alfalfa is well-adapted to growth in these areas. It is drought-resistant, but has the ability to regrow when moisture becomes available. Alfalfa does not require nitrogen fertilizer, which, if applied to dryland pastures, may be of questionable economic benefit where cash returns are relatively low and where moisture availability may limit the use of fertilizer nitrogen.

As a result of previous plant-breeding efforts we have hardy, creeping, rooted varieties that can survive the long, cold winters and trampling damage by grazing cattle. These and other attributes of alfalfa as a pasture and range forage crop are presently restricted by its bloat potential. The development of a bloat-safe alfalfa variety would double or triple the carrying capacity of Canada's extensive dryland pastures and rangelands. ■

UNE NOCTUELLE DÉPRÉDATRICE DANS LES POMMERAIES ET LES FRAISIÈRES

R. O. PARADIS

The results of research on the speckled green fruitworm, *Orthosia hibisci*, lead us to believe that the females of this species prefer a freshly worked soil for laying their eggs. On the other hand, studies have shown synthetic pyrethroids and Dimilin provide excellent protection against *Orthosia hibisci.*

Des études sur la noctuelle du fruit vert *Orthosia hibisci* (Guenée) ont été entreprises suite aux attaques répétées et généralisées de cet insecte dans les pommeraies du sud-ouest du Québec. En outre, les pomiculteurs éprouvaient des difficultés à protéger efficacement leurs vergers contre ce déprédateur. On a à différentes reprises noté la présence de l'espèce *O. hibisci* au Canada, notamment, sur plusieurs essences forestières, mais elle n'avait jamais fait l'objet d'observations suivies.

Les résultats préliminaires de ces études indiquent que, sous les conditions climatiques du sud-ouest du Québec, les adultes font leur apparition à la fin d'avril ou au début de mai, lorsque les pommiers McIntosh sont au stade du débourrement. Ce sont des papillons gris beige dont la tête et le thorax sont densément recouverts de poils (Fig. 1). L'envergure des ailes antérieures varie de 38 à 43 mm; ces ailes sont marquées par une ligne subterminale qui se brise en la région costale. Sur les ailes postérieures, on note à la partie centrale la présence d'une tache plus ou moins foncée en forme de demi-lune. Ce dernier caractère peut servir à l'identification rapide de l'espèce.

Le développement larvaire sur les pommiers s'échelonne du stade du bouton rose jusqu'à quinze jours environ après la chute des pétales, période qui se situe habituellement de la mi-mai à la mi-juin. Les larves de cette noctuelle sont vert pâle, légèrement lignées de blanc. Très voraces, elles attaquent les bourgeons et le feuillage en croissance ainsi que les fruits dès qu'ils sont formés. Sur les petites pommes, les larves pratiquent des morsures et des cavités profondes caractéristiques (Fig. 2). Bon nombre de pommes attaquées tombent prématurément, tandis que celles qui parviennent à maturité portent des lésions cicatrisées.

Au terme de leur développement, les larves mesurent de 30 à 40 mm de longueur. Elles tombent alors au sol, ce qui a lieu principalement vers la mi-juin et ce qui marque la fin de la période de déprédation sur le pommier. Les larves pénètrent immédiatement à quelque 6 cm sous terre pour se transformer en chrysalides. C'est le stade et l'endroit d'hivernement de l'espèce qui n'a qu'une génération par année.

De 1975 à 1978 inclusivement, 17 produits insecticides ont été mis à l'essai contre *O. hibisci* dans des vergers de pommiers au Québec. Les résultats obtenus ont démontré que les pyréthrinoïdes de synthèse (Ambush et Belmark), ainsi que le Dimilin, un benzoyl urée qui agit comme inhibiteur de croissance chez les larves, assuraient une très bonne protection contre cet insecte et pourraient éventuellement remplacer le Guthion, qui est présentement l'insecticide recommandé.

R. O. Paradis est chercheur scientifique à la Station de recherches de Saint-Jean.

Figure 1 Papillon ou forme adulte d'*Orthosia hibisci*

Pour compléter cette information sur cette noctuelle, il faut ajouter que, en 1977 et 1978, elle a étendu ses ravages à des fraisières nouvellement plantées. Ainsi, en 1977, on a estimé que le nombre de plants attaqués par les larves d'*O. hibisci* représentait respectivement 27 et 31 pourcent chez les cultivars Redcoat et Bounty dans une nouvelle plantation à Frelighsburg, Québec. En 1978, les larves étaient présentes dans les fraisières des localités de l'Acadie, Saint-Grégoire, Bedford et Frelighsburg, i.e., dans chacune des quatre fraisières inventoriées et la proportion des plants attaqués variait de 4 à 15 pourcent.

Les jeunes larves enroulent les feuilles de fraisiers, se constituant ainsi un abri à l'intérieur duquel elles grugent le paranchyme foliaire. Les larves plus âgées se tiennent à la face inférieure des feuilles et dévorent littéralement le limbe en pratiquant ici et là des trous et des échancrures (Fig. 3). Ces défoliations peuvent compromettre la croissance et la survie des plants. Comme les attaques se concentrent sur les fraisiers nouvellement plantés, on en déduit que les femelles d'*O. hibisci*, comme il arrive chez quelques autres espèces de noctuelles, recherchent de préférence un sol fraîchement remué pour y déposer leurs œufs. ■

Figure 2 Pommes avec lésions cicatrisées suite aux attaques d'*Orthosia hibisci*

Figure 3 Dégâts d'*Orthosia hibisci* sur feuilles de fraisier

BIOLOGICAL CONTROL OF SCLEROTINIA WILT IN SUNFLOWER

H. C. HUANG

Les résultats de deux années d'essais sur le terrain indiquent que *C. minitans,* seule ou conjuguée à *G. catenulatum* et *T. viride,* réduit de façon efficace le flétrissement dû à Sclérotinia et, en conséquence, augmente le rendement du tournesol.

Sclerotinia disease caused by the soil-borne pathogen *Sclerotinia sclerotiorum* (Lib.) de Bary is highly destructive to many crops under field, greenhouse, storage, transit and market conditions. The pathogen attacks more than 360 species of plants in 64 families including sunflower and rapeseed. In North America, Sclerotinia disease of sunflower was first recorded in 1912 but it received little attention until 1920 when the disease was reported as common and destructive to the cultivated sunflower in Canada and the United States. Due to the rapid increase of sunflower acreage in the past two decades, this disease has become one of the limiting factors in sunflower production in Western Canada.

The pathogen survives in soil by the black resting bodies or sclerotia which vary greatly in size, ranging from 2 mm to over 50 mm (Fig. 3). During the sunflower growing season, the sclerotia may germinate to produce mycelia which may attack sunflower roots causing root rot, basal stem canker and wilt of the plant (Fig. 1); or, under certain environmental conditions, the sclerotia may germinate to produce airborne ascospores which may attack sunflower heads causing head rots (Fig. 2). Both types of infections occur in the sunflower production area of Manitoba, but wilt is generally more severe than head rot.

Figure 1. Infection of sunflower roots by *Sclerotinia sclerotiorum* causing sudden wilt and death of the plant.

Figure 2. Infection of the sunflower head by *S. sclerotiorum* resulting in a brush-like appearance.

Both Sclerotinia wilt and head rot can cause severe yield losses in sunflower. A field study was conducted in 1977 to investigate the effect of Sclerotinia wilt on yield and quality of sunflower. Results showed that a field with 60% Sclerotinia wilt would cause a 37% reduction in seed yield. The same study showed that seed quality, measured by test weight, oil content, and protein content, was significantly reduced if plants wilted within 6 weeks of flowering. Commercial sunflower fields with more than 80% Sclerotinia wilt were frequently found in Manitoba each year. The yield losses in such fields would undoubtedly be higher than 37%.

Sclerotinia head rot was widespread in the Manitoba sunflower-production area, but the disease was generally light in most of the fields. However, a severe outbreak of head rot occurred in 1977 due to excess rainfall at the flowering and seed-development stages of sunflower growth. Fields with severe head rot could result in poor seed yield and poor seed quality because of heavy contamination of seeds by sclerotia of *S. sclerotiorum.* For instance, a sunflower field at Brookdale, Man., showed 85% of Sclerotinia head rot in 1977. The seed samples for this field contained 4327 pieces, equivalent to 273 g, of sclerotia in each kg of seed.

The Sclerotinia disease of sunflower is one of the most difficult to control due to the nature of long persistence of sclerotia in the soil and rapid growth and spread of hyphae in the diseased tissue. Since sclerotia are the main overwintering

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structures of this pathogen, serving as a primary source of inoculum for both Sclerotinia wilt and head rot of sunflower, it is of paramount importance to control the disease via the control of sclerotia in the field. A study was initiated in 1975 at the Morden Research Station to search for soil microorganisms that were parasitic to *S. sclerotiorum* for use as biological control agents. Several fungal species not harmful to sunflowers, including *Coniothyrium minitans* Campbell, *Gliocladium catenulatum* Gilman & Abbott, and *Trichoderma viride* Pers. ex Fr. could attack and kill sclerotia of *S. sclerotiorum* by direct parasitization. For example, when the sclerotia of *S. sclerotiorum* were attacked by *C. minitans*, numerous, dark-colored fruiting bodies (or pycnidia) of the hyperparasite were formed on the internal (Fig. 4) and external tissue of the sclerotia, which often decayed and disintegrated as a result of infection.

The efficacy of these hyperparasites against their target host was evaluated under greenhouse conditions by burying sclerotia in the hyperparasite-treated soil. Results showed that after an incubation of 100 days, the sclerotia was reduced to 3, 67 and 42% in the soil treated with *C. minitans, G. catenulatum* and *T. viride*, respectively; the amount of sclerotia in the untreated soil was increased to 114% due to the formation of new or secondary sclerotia during incubation. This study suggests that among the three hyperparasites, *C. minitans* is most effective in controlling sclerotial population of *S. sclerotiorum*.

The efficacy of these three hyperparasites were further tested in 1976 and 1977 in field plots naturally infested with sclerotia of *S.*

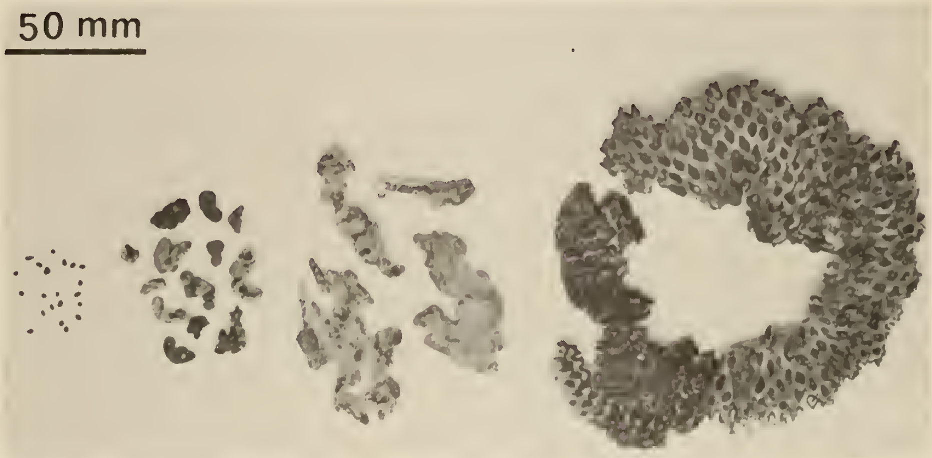

Figure 3. Sclerotia of *Sclerotinia sclerotiorum*, varying in size and shape, were collected from diseased sunflower tissue

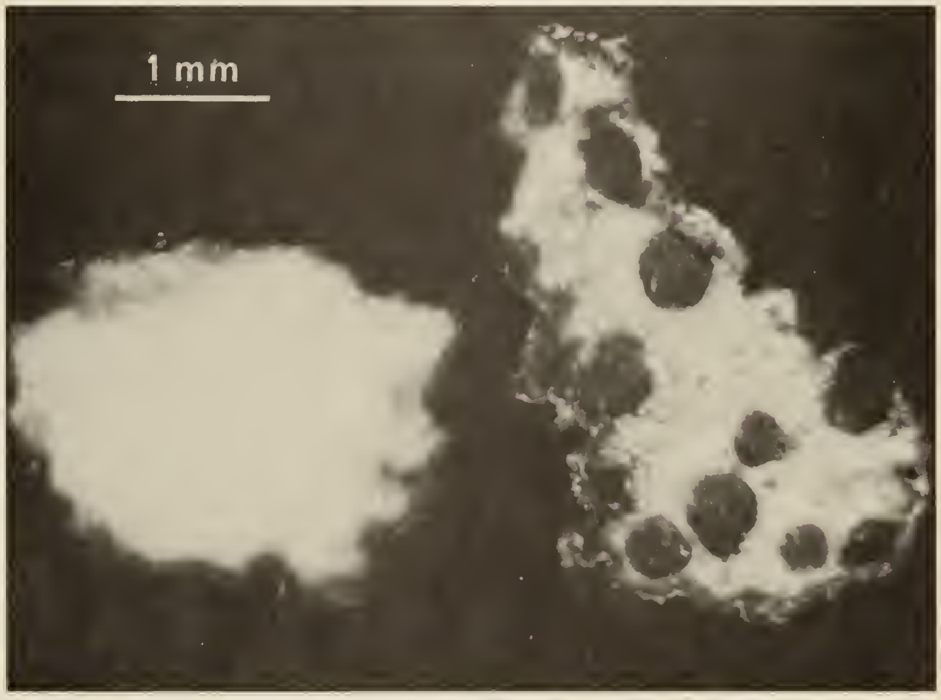

Figure 4 A sclerotium infected by *Coniothyrium minitans*, showing numerous pycnidia (dark spots) inside the sclerotium tissue (right), and a healthy sclerotium with white internal tissue (left).

TABLE 1. EFFECT OF HYPERPARASITES ON SCLEROTINIA WILT AND YIELD OF SUNFLOWER IN 1976 AND 1977.

Treatment[a]	Disease (%)[c] 1976	Disease (%)[c] 1977	Yield (kg/ha)[c] 1976	Yield (kg/ha)[c] 1977
1 Check	43	40	1213	902
2 C	25 B	24 B	1495 B	1121 B
3 C+G+T	21 B	23 B	1473 B	1085 B
4 [b]	25 B	23 B	1539 B	1103 B

[a]C, *Coniothyrium minitans;* G, *Gliocladium catenulatum;* T, *Trichoderma viride.*

[b]The treatment for 1976 was C+G+T with two applications (first application at seeding; second application at 8 weeks after seeding); and for 1977 was C alone but air-dried.

[c]Means within columns followed by the same letter are not significantly different at the 0.05 level (Duncan's multiple range test).

TABLE 2. EFFECT OF *CONIOTHYRIUM MINITANS* ON SCLEROTINIA WILT AND YIELD IN SUNFLOWER IN 1978.

Treatment	Disease (%)[a] Field 1	Disease (%)[a] Field 2	Yield (kg/ha)[a] Field 1	Yield (kg/ha)[a] Field 2
Check	18 A[b]	43 A	1003 A	635 A
Coniothyrium minitans	8 B	11 B	1030 A	912 B

[a]Field 1, natural infestation; field 2, artificial infestation of *S. sclerotiorum.*

[b]Means within columns followed by the same letter are not significantly different at the 0.05 level (t-test of paired samples).

Figure 5. Control of sclerotinia wilt of sunflower by the hyperparasite *Coniothyrium minitans.* Note the difference in the amount of wilted plants between hyperparasite-treated (right two rows) and untreated plots (left two rows).

sclerotiorum. Hyperparasites were applied to the soil at the time of seeding. Results of the 2-year field trials showed that either *C. minitans* alone or a combination of the three hyperparasites was effective in controlling Sclerotinia wilt and, consequently, increasing yield in sunflower. The Sclerotinia wilt was less than 25% in the hyperparasite-treated plots and over 40% in the untreated controls (Table 1). However, there was no significant difference in incidence of wilt between the treatment of *C. minitans* alone and that of the three hyperparasites together.

In 1978, *C. minitans* was field tested for the third year. Again the incidence of Sclerotinia wilt in the hyperparasite-treated plots was significantly lower than that of the untreated controls in both artificially (Fig. 5) and naturally infested fields (Table 2). However, the yield difference between hyperparasite-treated and untreated plots was significant only in the field artificially infested with *S. sclerotiorum* (Table 2).

From results of the 3-year field trials, it appears that mass introduction of hyperparasites to the soil, *C. minitans* in particular, is effective in controlling Sclerotinia wilt and reducing yield losses in sunflower. The biological-control method may have great potential as a supplement to the cultural practices recommended for the control of Sclerotinia wilt in sunflower. ■

RESIDUAL EFFECT OF BORON ON CEREAL

UMESH C. GUPTA and
J. A. CUTCLIFFE

La culture des céréales après pulvérisation du rutabaga ou une autre culture pulvérisée au taux de 2 à 4,5 kg B/ha ne présente aucun danger d'intoxication au bore.

Cereals are generally considered to be sensitive to moderate to high levels of boron (B) in the soil. Field experiments carried out in Prince Edward Island showed that applications of 2.24 kg B/ha immediately prior to seeding resulted in reduced yields of wheat and barley. On the other hand, levels of 2.24 kg B/ha are quite normal for rutabaga, cole crops and forage legumes which may suffer from B deficiency.

In experiments conducted in P.E.I., less than half of the B applied broadcast was recovered in the hot-water-soluble extracts of the soil 5 months after application. Hot-water-soluble B in soil is considered to be available to plants. Therefore, it was assumed that B applied to a preceding crop may not be as detrimental to a following crop as generally considered. Since no information was available on the residual effect on cereals of B applied to a previous crop, field experiments were conducted to determine the effects on wheat and barley of recommended and higher levels of B applied to a preceding rutabaga crop.

Experiments carried out in P.E.I. at six locations over 3 years indicated that B applications as high as 8.96 kg/ha to a rutabaga crop were not detrimental to succeeding crops of wheat and barley (Table 1). In Eastern Canada the recommended rates of B for rutabaga vary from 2 to 4.5 kg/ha. Thus, there should be no B toxicity problem in growing cereals following rutabaga that received recommended levels of B. Based on the results of this study, it is concluded that cereals can be grown without danger of B toxicity following rutabaga or any other crop that received recommended rates of 2 to 4.5 kg B/ha. ■

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TABLE 1. EFFECT OF B, APPLIED TO A PRECEDING RUTABAGA CROP, ON THE YIELDS OF WHEAT AND BARLEY.

Year rutabaga sown	Crop year	Rates of B applied (kg/ha)			
		0	2.24	4.48	8.96
		Ten Mile House			
		grain yields, kg/ha light, fine, sandy loam soil texture; pH 5.7; organic matter, 3.0%			
1975	Wheat, 1976	2254	2120	2109	2267
1975	Barley, 1976	3456	3667	3513	3631
		Kingston			
		fine, sandy loam soil texture; pH 5.9; organic matter, 3.4%			
1975	Wheat, 1976	3318	3313	3257	3282
1975	Barley, 1976	4241	4130	4175	4063
		Valleyfield			
		fine, sandy loam soil texture; pH 5.7; organic matter, 2.8%			
1976	Wheat, 1977	3112	3252	3110	3029
1976	Barley, 1977	3884	3745	3788	3946
		Fort Augustus			
		fine, sandy loam soil texture; pH 5.9; organic matter, 2.7%			
1976	Wheat, 1977	3446	3464	3407	3418
1976	Barley, 1977	2931	2999	2979	2671
		West Royalty			
		fine, sandy loam soil texture pH 5.8; organic matter, 3.9%			
1977	Wheat, 1978	2612	2150	2717	2358
1977	Barley, 1978	3823	4072	4097	3969
		Dunstaffnage			
		sandy loam soil texture; pH 6.2; organic matter, 2.9%			
1977	Wheat, 1978	2496	2252	2180	2183
1977	Barley, 1978	4734	4712	4621	4485

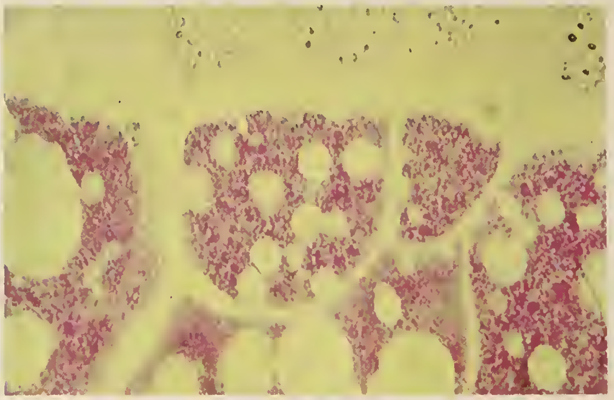
INSIDE CEREALS — A MICROCHEMICAL VIEW

R. G. FULCHER and
S. I. WONG

Les variations chimiques qui se produisent dans les graines des céréales déterminent leurs caractéristiques physiologiques, nutritives et technologiques. Il faut donc établir la nature et l'importance de ces variations qui sont la base de toute amélioration. La microscopie à fluorescence possède certains avantages sur la microscopie optique pour l'analyse des céréales du fait qu'elle dispense d'utiliser des spécimens relativement minces, fournit rapidement des données sur les surfaces des feuilles et des graines sans perte de résolution et assure une meilleure spécificité chimique.

Mature cereal grains are complex biological systems. They contain an awesome array of biochemical constituents which are synthesized, packaged and stored in different seed tissues. They may vary considerably in concentration or chemical and morphological form depending on their genetic background and the environmental conditions in which the plants were grown. Since these differences determine the physiological, nutritional and processing characteristics of cereals, it is important to establish their form and extent to provide a basis for further improvement.

At the Ottawa Research Station we recently established a microchemical facility to define more precisely for our breeding programs some of the physiological and structural interactions within cereal grains that most influence grain quality and behavior. Occasionally



Figures 1 and 2. Conventional light micrographs of equivalent endosperm tissues from two oat cultivars after staining for protein. Note the dramatic morphological differences in the protein (red-stained) deposits of the two specimens.

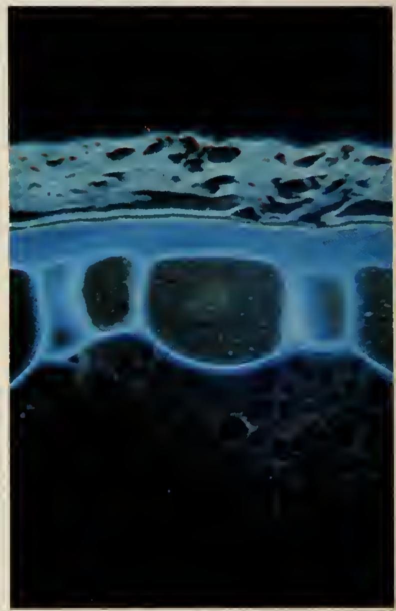


Figure 3. A fluorescence micrograph of a section of wheat bran showing intense blue autofluorescence which is indicative of high concentrations of ferulic acid in the aleurone layer.

Dr. Fulcher and Mr. Wong are members of Agriculture Canada's Ottawa Research Station.

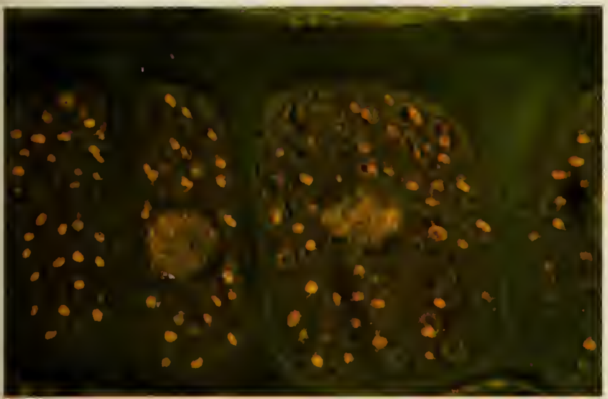
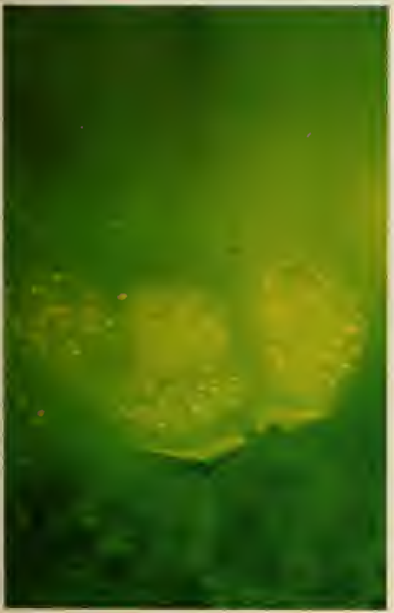


Figure 4. A fluorescence micrograph of a section of wheat bran showing orange fluorescence in nicotinic acid deposits after reaction of the specimen with cyanogen bromide and *p*-aminobenzoic acid.



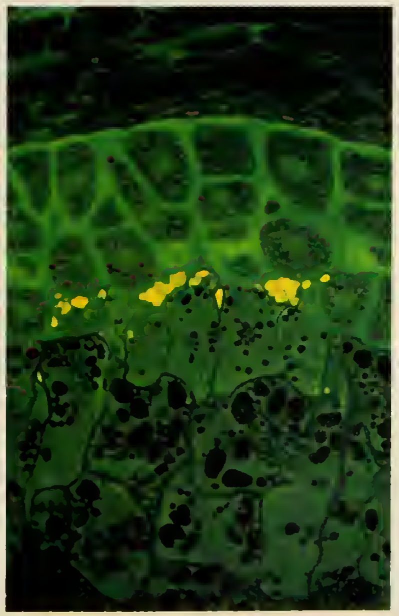


Figure 5. A fluorescence micrograph of a section of barley bran showing yellow fluorescence in deposits of aromatic amines

Figure 6. A fluorescence micrograph of barley endosperm showing yellow fluorescence after Aniline Blue staining The chemistry of the fluorescent structures is unknown, but there is considerable variation in their morphology in different cultivars.

Figures 7 and 8 Fluorescence micrographs of two oat cultivars after treatment with Calcofluor White (blue fluorescence) showing distinctive differences in cell wall morphology.

we employ conventional light microscope staining procedures for assessing variation within and between cultivars (e.g. in protein morphology and distribution, Fig. 1 and Fig. 2), but for the most part we rely on a fluorescence microscope with a high-intensity mercury arc lamp and epi-illuminating system.

Fluorescence microscopy is based on the principle that many compounds emit visible light, or fluorescence, at specific wavelengths and of sufficient intensity to induce the fluorescence. A fluorescence microscope is a normal bright field microscope with an illuminator to provide strong output at short wavelengths (primarily in the blue region) and a range of filters that control the excitation wavelengths and separate the final fluorescence image from this excitation illumination.

Fluorescence microscopy has several advantages over conventional microscopy for cereal analysis. For example, detection of fluorescent compounds is improved by increasing the intensity of the excitation illumination, a feature not shared by bright field systems and conventional microscopic stains. To this end, several manufacturers provide epi-illuminating systems that significantly increase both the intensity of the incident illumination and the resulting fluorescence. Because they illuminate the *surface* of microscopic specimens, epi-illuminators offer the added advantages of obviating the usual microscopic requirement of relatively thin specimens, and of rapidly providing information about leaf and grain surfaces without loss of resolution.

The fluorescence approach also provides superior chemical specificity since the color of the emitted light is a function of the chemistry of the fluorescing substance. Although not all cereal components are naturally fluorescent (i.e. *autofluorescent*), those that are can be detected and identified readily in tissue sections without any pretreatment of the specimen. For example, phenolic compounds are often strikingly autofluorescent and one common cereal phenolic, ferulic acid (Fig. 3), has on several occasions been located and quantitated in tissue fractions by simple fluorescence methods. Once autofluorescence patterns are established for a particular seed type, it becomes a relatively simple matter to detect differences between cultivars, determine developmental patterns, or to assess the distribution of tissue components in milled fractions.

Non-fluorescent cereal substances can be seen by adapting specific chemical treatments to produce fluorescent reactions. The spectacular concentrations of nicotinic acid in wheat bran are recognized readily following treatment with cyanogen bromide and *p*-aminobenzoic acid (Fig. 4). Aromatic amines, which are associated with the nicotinic acid reservoirs, can be detected by methods that also produce fluorescent reactions (Fig. 5). This simple approach has yielded considerable information about cultivar differences in relation to these compounds and provides additional chemical markers for following the fate of specific tissues through processing systems.

Although many cereal components neither autofluoresce nor lend themselves readily to the formation of fluorescent reaction products, this in no way limits the usefulness of fluorescence microscopy. In recent years, there has been a dramatic increase in the number of intensely fluorescent dyes capable of binding with biological molecules. Some of these molecules have a high degree of specificity for certain chemical groups, while for others (e.g. Aniline Blue, Fig. 6) the specificity is morphological only and chemical definition remains unknown. In either case, fluorescent markers are vastly superior to older, conventional, bright field staining methods because of the markedly improved contrast and sensitivity afforded by fluorescence methods.

One of these fluorescent markers, Calcofluor White, has a high specificity for endosperm cell walls. The chemical mechanism of its interaction with cell walls is not yet established, but the compound provides the most sensitive marker yet encountered for cell walls. Using Calcofluor and related compounds, we have found significant differences in cell wall organization between several different oat and barley cultivars (Figs. 7 and 8). We are exploring the potential of such markers for cultivar identification and to provide rapid chemical assays for cell wall carbohydrate content in different cereals.

In summary, it is our view that the microscope will continue to aid in unravelling many of the mysteries of cereal grain composition and organization, provided that the instrument is used as a *chemical* tool in conjunction with specific markers for grain constituents. The program at ORS is still in its formative stages, but to date we have identified more than 20 such markers possessing varying degrees of chemical specificity for grain components. Using these markers, it is clear that certain cultivar-specific characteristics may be readily iden-

tified, and we have successfully adapted some of these microchemical reagents to rapid semi-quantitative screening of single seeds. The fluorescence microscope is perhaps the most useful of all microscopic equipment for cereal analysis. Its sensitivity, chemical specificity, and ease of specimen preparation are greater than for any other optical system and, except in rare circumstances where extremely high resolution is required, it is preferable to electron microscopic systems. We anticipate that the fluorescence microscope will rapidly become a standard item in many cereal laboratories. ■

STOP PESTICIDE LOSS IN SPRAY MIXTURES

MIKO CHIBA

Les auteurs recommandent d'utiliser le plus tôt possible des antiparasitaires dilués avec de l'eau alcaline, faute de quoi il y aura dégradation du produit et diminution de son efficacité.

Water plays a major role in controlling pesticides' rate of decomposition and environmental impact. Pesticides are applied as emulsions or suspensions in water, and often end up in streams, rivers and lakes. Many organophosphorus pesticides[1], such as malathion, and carbamate pesticides[2], such as carbofuran, are hydrolized under alkaline conditions. In water, hydrolysis of these pesticides increases sharply at pH levels higher than 7, and the rate increases approximately tenfold with each additional pH unit[3].

In the Holland Marsh, where a large percentage of Ontario vegetables are grown, there have been many occasions when the pesticide did not give the level of insect or disease control expected. After investigating many factors in co-operation with Matt Valk, senior muck crops specialist, Ontario Ministry of Agriculture and Food, we concluded that the culprit was probably the water used in preparing the pesticide for application. Most of the water used in the Holland Marsh is fairly alkaline (pH 7.5-9.0). However, many waters in the Niagara Peninsula, and possibly in other districts of Canada, are equally alkaline.

It is appropriate, therefore, to recommend that pesticides diluted with alkaline waters be used immediately. Any delay applying spray mixtures — because of sickness, equipment breakdown or unex-

[1]Eto, M. 1974. "Organophosphorus Pesticides: Organic and Biological Chemistry", CRC Press, Inc., Cleveland, Ohio, pp 1-387.

[2]Kuhr, R. J. 1976. Dorough, H.W., "Carbamate Insecticides: Chemistry, Biochemistry and Toxicology", CRC Press, Inc., Cleveland, Ohio, pp 1-301.

[3]O'Brien, R. D. 1967. "Insecticides, Action and Metabolism", Academic Press, New York, N.Y. pp 1-331.

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pected weather conditions — will result in pesticide degradation and a corresponding decrease in pest control. More pesticide applications will be needed, resulting in increased crop-production costs and further environmental pollution.

To overcome pesticide decomposition in alkaline water and to retain pesticide biological activities, acids and nutrient spray acidifiers were tested[4]. With these materials, however, it was impossible to maintain the pH constant enough for practical use. Some pesticides are susceptible to acid hydrolysis[1], and others are hazardous to honeybees if the pH of diluted material is too low[4].

The ideal water for dilution of pesticides is neutral or slightly acidic. A simple procedure to reduce and stabilize the pH of alkaline waters was developed at the Vineland Research Station. Either monoammonium phosphate or monopotassium phosphate lowered the pH of the majority of water samples to 6.6 – 6.9 when added at the rate of 0.5 g/L of water. To dilute pesticides prior to commercial application 0.225 kg of the phosphate should be dissolved in each 450 L of water.

Although pH is the key factor indicating the possibility of alkaline hydrolysis of pesticides, it does not indicate the magnitude of buffer capacity of water. If the buffer capacity of the water is exceptionally high, it may be necessary to increase the quantity of the phosphate added (for example, 1 g/L) for satisfactory control.

Use of these compounds has an added advantage. Monoammonium phosphate and monopotassium phosphate are both well-recognized fertilizers; the small amount applied along with pesticides may serve as a foliar nutrient. On occasion water soluble fertilizers are used with pesticides as a tank mixture. Although most dry fertilizers are acidic, most soluble fertilizers used in the Holland Marsh area are strongly alkaline. As a result, the pH of the diluted pesticide remains high and the problem of pesticide hydrolysis is increased. Clearly 0.225 kg of phosphate/450 L of water would be insufficient to lower the pH to the required level. Adding any alkaline fertilizer to the sprayer tank is not encouraged.

The cost of the phosphate is extremely small (40¢) relative to pesticides (as much as $30) per 450 L of water. Hence, it is worthwhile to use either one routinely as insurance against pesticide hydrolysis. Moreover, as there is no need to increase the amount of pesticide added to the tank to compensate for losses due to hydrolysis, nor to apply extra sprays, a saving in pesticide costs is highly probable. There is also the added benefit that any reduction in total pesticide use contributes to a clean environment. ■

[4]Johansen, C., and Eves, J. 1972. J. Econ. Entomol. *65*, 546-551. ■

POTATO WART DISEASE IN NEWFOUNDLAND

M. C. HAMPSON

Des recherches suggèrent que les facteurs intervenant sur la persistance de la tumeur verruqueuse de la pomme de terre à Terre-Neuve comprennent l'humidité du sol, sa température de même que le mode de germination du champignon.

Wart disease or "canker" of potatoes is endemic in Newfoundland; spread of the disease from this province is prevented by plant quarantine regulations administered by Agriculture Canada's Plant Quarantine Division.

At the St. John's West Research Station, we seek to idencify factors that affect the development of the potato wart fungus in the Newfoundland soil, climate and biological context.

In earlier experiments (Canada Agriculture, Winter, 1977), we learned that one irrigation complex favored infection more than the others. The best infection occurred when tubers were irrigated for the first 2 weeks of planting. Infection

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levels were also dominated by the season. We found that:

— Less disease was produced as the year (Jan.–Sept.) marched on; and
— The disease peaked three times during the experimental period.

These peaks appeared to coincide with the production of susceptible tissues by the potato plant; that is, sprout, stolon bud and eye. The facts suggest that the fungus, to some extent, controls its own germination rate.

We compared further irrigation treatments.

On a greenhouse bench planted to infested tubers, we irrigated one half for the first week of planting and the other half for the second week. During the irrigation-off weeks, daily light watering was used. In Table 1 are grouped several parameters measured at harvest from six experiments covering a 6-month (Jan.–June) period. The outstanding values are the ratio of tumor to potato-top growth, (50% higher for second-week irrigation), and the average numbers of tubers/plant (60% lower for second-week irrigation). The differences are related to the reduction in plant growth for second-week irrigation, likely due to an increase in the number of infection foci.

Minor differences were noted between the percentage of infections in the first and second series of irrigation experiments. In Figure 2 we graphically present the different irrigation schemes for the first 3 weeks of planting, and rank them in order of success.

From these results, we would expect that infection is optimized in the field when precipitation is intermittent.

TABLE 1. COMPARISON OF PARAMETERS MEASURED 8 WEEKS AFTER IRRIGATING POTATO TUBERS (INFESTED WITH POTATO WART FUNGUS) TO EXCESS IN FIRST OR SECOND WEEK OF PLANTING.*

	Week of Irrigation	
Parameter	First	Second
Percent infection	77	78
Ave. number of tumors/plant	8	7
Ave. weight of tumor	2.1 g	2.3 g
Ave. number of tubers/plant	5	2
Ave. weight of tuber	10 g	8 g
Weight of tumor/kg of top growth	109 g/kg	146 g/kg

*The results are the averages of six experiments carried out in January-June.

Figure 1. A typically "warted" plant.

In Table 2, we present data gathered at the Research Station for precipitation during the potato-planting time, June 1 to June 21 over a 5-year period. The average rainy period was 2.3 days, and the average dry period, 2.6 days. Therefore, there is an almost equal chance of having a rainy or dry period during planting time. The on-off precipitation (often heavy) undoubtedly influences potato wart disease and is one of the factors responsible for its persistence in Newfoundland.

As the sprout grows it becomes less susceptible to infection because the protective tissues suberize and thicken (Fig. 1). So the active infection period is near the beginning of the planting period. Hence, conditions at that time are particularly significant for persistence of the disease.

Not only is soil moisture a dominant factor, but so is soil temperature. We planted infested tubers in soil subject to an irrigation pattern at temperatures that were reduced as the season progressed. In the soil bench, the temperature was gradually reduced to 10°C from 18°C in 4 experiments. The fact that infection rose as temperature fell indicates that temperature is a limiting

TABLE 2. RAINY DAYS IN THE FIRST 3 WEEKS OF JUNE FOR A 5-YEAR PERIOD AT ST. JOHN'S WEST, NFLD.

YEAR	DAYS OF THE MONTH 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	TOTAL RAINFALL (mm)	% DAYS WITH RAIN
1976	X					X	X					X	X		X							28.9	28
1975	X	X	X		X	X	X	X	X	X	X			X	X		X	X	X			57.3	71
1974	X			X	X	X	X	X	X		X	X	X						X			46.8	52
1973				X						X	X			X	X		X	X				132.7	33
1972	X		X		X	X	X				X						X					49.0	33

factor in potato-wart-disease production.

The graph of the tumor: top-growth ratios for irrigation in the second week of planting (Fig. 3) clearly shows that when the bench conditions simulate field conditions there is a greater expression of disease. This graph also shows unequivocally the cyclic disease phenomenon. It seems that this ebb is related to temperature build-up in the soil. It indicates the importance of controlling the planting conditions, and of the caution needed in comparing results from experiments carried out at different times of the year.

To look at the phenomenon of cyclical or periodic infection from another angle, we turned our attention to the fungus itself. Since the fungus that causes potato wart disease does not produce a vegetative mycelium, and reproduces by swimming zoospores, it is difficult to estimate to what extent it is capable of growing. By measuring the changes in maturity of populations of the fungus over a long time, we can estimate its rate of germination and its germination pattern. Thus when maturity falls, we suppose it is because there has been an increase in germination of the fungus. From putting together the changes in maturity patterns of many populations subject to different incubation media, we arrived at a valuable picture of the germination pattern of the fungus.

The maturity falling at first (Fig. 4) is akin to a burst in germination. Viability begins to increase during the next 6 weeks, the maturation phase of the fungus. Another burst of germination takes place, followed by further maturation. This pattern helps to explain the bursts of infection that we observe on our greenhouse benches.

As a wart-fungus population appears to lose 10% of its members at each pulse of germination, the half-life of a population works out at about 2½ years. In our work, we can extract 1,000,000 sporangia from 20g of wart tumor. In field experiments, we often gain a yield of 100g wart tumor/plant. Thus, undisturbed, the fungal population from one plant would reduce from 5,000,000 to 10,000 in 22 years, ample inoculum to bring about infection.

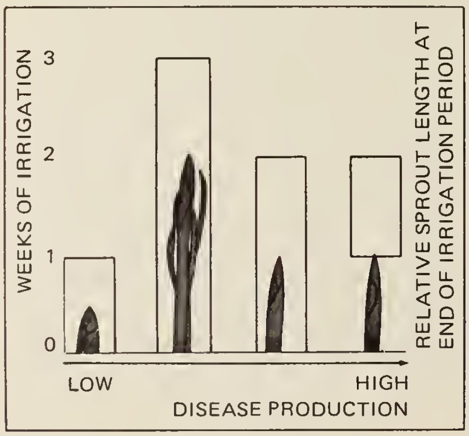


Figure 2. Irrigation schemes ranked according to success in disease production, depicting relative sprout lengths at the ends of irrigation periods.

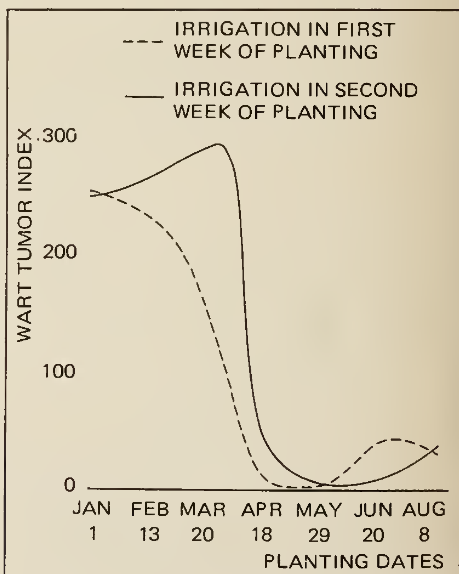


Figure 3. The wart-tumor index[1] changes with the season, but is also influenced by excess water.

[1]Tumor weight: weight of parent potato top growth = wart tumor index.

In fact, viable sporangia can be found 30-40 years after production. Imagine many plants producing tumors for a long time, and it is apparent that the germination pattern of the fungus is another factor leading to persistence of wart disease in Newfoundland.

In conclusion, we should point out that there are other factors that enhance, or have enhanced, the persistence of wart disease. For example, spread of the fungus is limited almost entirely to movement of contaminated soil (infested potatoes, contaminated cultivating implements, etc.). Thus, lack of knowledge of the means of dissemination of the fungus leads to persistence of the disease. We know of many cases where the disease has been unknowingly introduced into kitchen gardens with damaging results. Another factor has been continuous cropping in the same garden plot for decades. This practice has led — again unknowingly — to an overabundance of the fungus.

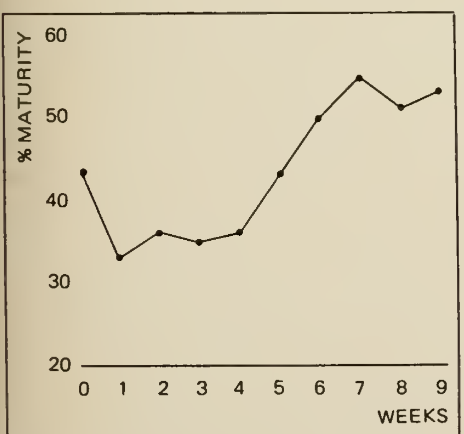


Figure 4. The loss of maturity is probably due to loss of viable sporangia as they germinate; the increase due to the maturation the fungus undergoes before it becomes germinable.

Apart from the persistence factors we have examined at the Station, there are other, subtler, factors that invite examination. For example, nothing is known about the relationships between the potato's infection court tissue (such as a sprout), wart fungus, and the microbial populations in the surrounding soil. Are there microbial complexes in Newfoundland soils that uniquely aid in persistence of the fungus, that aid in germination, that mediate — in ways not yet known — the infective relationship of the fungus and the potato plant? ■

NEMATODE PROBLEMS IN MUSHROOM PRODUCTION

TH. H. A. OLTHOF and
F. J. INGRATTA

Des expériences poursuivies à la Station Vineland ont révélé que les nématodes saprophages n'affectent pas directement la croissance des champignons de couche. Les auteurs en concluent qu'une forte population de nématodes, attribuable à un excès d'humidité, ne diminue pas le rendement.

Commercial mushroom production in Canada started in 1912, expanded rapidly after 1950, and is growing at the rate of nearly 15%/year. Among vegetables in Canada, only potatoes and tomatoes outrank mushrooms in farm-gate value. Of the 22 million kg produced by 150 growers in 1977, 75% was for the fresh market and 25% was canned. In 1977, Canada also imported 340 000 kg of fresh mushrooms from the U.S., and nearly 16 million kg drained weight of canned mushrooms from the Far East. The annual per capita consumption in Canada is approximately 1.9 kg.

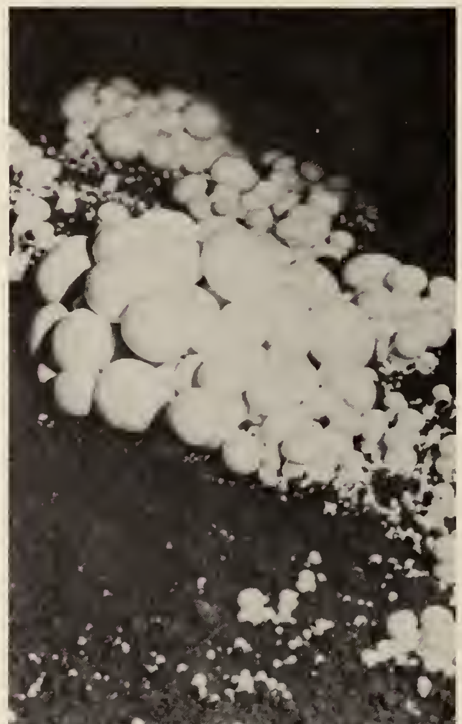
Dr. Olthof is a nematologist at the Agriculture Canada Research Station and Mr. Ingratta a research scientist at the Horticultural Research Institute of Ontario, both at Vineland Station, Ontario.

Growing cultivated mushrooms (*Agaricus brunnescens*) requires a rigidly controlled environment with exacting attention to temperature, humidity and ventilation. Mushrooms are grown in trays or beds in specially constructed mushroom houses. Mushroom spawn (grain covered with mycelium) is sown

on pasteurized compost consisting mainly of horse manure mixed with hay, corn cobs, poultry litter, brewers' grain and gypsum. When the mycelium has thoroughly permeated the compost (12-16 days), a 3-4 cm layer of casing material (soil or peat moss mixed with limestone) is placed on top. About 3 weeks after casing, pinheads or tiny mushrooms begin to appear. One week later, the first break or flush is harvested. Succeeding flushes occur in 8-10 day intervals, declining in yield until harvesting stops after 6-7 weeks. In general, three crops are grown/year with yields averaging about 15 kg/square meter/crop.

Molds and parasitic fungi such as *Verticillium*, bacteria, viruses, flies, mites, and nematodes are the main diseases and pests of the cultivated mushroom. The key to a healthy crop is prevention by maintaining a high standard of sanitation at all times and a rigorous control of environmental conditions. Pesticides are used routinely to keep flies and fungi down to minimal levels.

Dr. Olthof (left) and Mr. Ingratta examine mushrooms in a tray at the Mushroom Research Unit.



Nematodes, which are microscopic, eel-shaped worms, often associated with mushroom-growing, are of two basic types. The mycophagous or fungus-feeding nematodes, such as *Ditylenchus myceliophagus* and *Aphelenchoides composticola*, reduce yields through direct feeding on mushroom mycelium. Fortunately these stylet-bearing nematodes have never been found in any of the 3,000 growers' and research samples submitted for examination at Vineland Station. The second type of nematode is the saprophagous or bacteria-feeding nematode, of which species of *Acrobeloides*, *Rhabditis* and *Choriorhabditis* are the most common. These are in almost all compost and casing samples, often in large numbers of up to 10,000/g. They are usually introduced as a result of inadequate cooking-out (pasteurizing) of the compost, from infested peat moss, or from the cracks and joints in the wooden trays or beds. When extremely abundant, they often move to higher parts of the bed, such as mushroom buttons or lumps of casing, where they writhe around each other forming glistening, waving spires visible to the naked eye. Since mushroom growers usually associate such phenomena with depressed yields, they expressed their concern to us about the role of these saprophagous nematodes in reducing yields.

The Vineland campus is uniquely suited to investigate nematode problems of mushrooms as it is the only location in Canada with a Mushroom Research Unit and a Nematology Section. We searched the literature

and discussed the problem with mushroom nematologists in the U.S., the U.K., France and the Netherlands. It soon became clear that little information was available and that many of the views expressed were contradictory. In our research, a small survey of mushroom growers showed that those who used chlorine as part of the watering program had fewer nematodes. In subsequent experiments, we found that chlorinated water reduced nematode populations only at the end of the crop; however, despite this reduction there was no effect on total yield of marketable mushrooms. In trials with three nematicides, all provided a measure of nematode control throughout the crop, with carbofuran proving the best control agent for the majority of the harvest cycle. Only oxamyl produced a negative effect on yield, while carbofuran and phenamiphos tended to increase yield. Again there was no significant correlation between nematode populations and mushroom yields.

Another experiment showed that carbofuran reduced nematode populations only when applied to the casing layer at the time of casing and 2 weeks after the first harvest. Applications 4 weeks after first harvest or to the surface of the compost prior to casing did not control the nematodes. In further experiments using carbofuran as a nematode-controlling agent, trays that were inoculated with nematodes at the time of casing produced a higher total yield than those not inoculated. Yields were positively correlated with nematode populations at casing, but the reverse was true when correlated with populations at the end of the harvest period.

These and other experiments lead us to the conclusion that saprophagous nematodes have no direct effect on the growth of the cultivated mushroom. Rather than being the cause of depressed mushroom yields, high nematode populations come about as a result of excessive moisture which favors bacterial development and limits mycelial growth.

Dr. Olthof (left) and Mr. Ingratta examine mushrooms in stacked trays in a cell of the Mushroom Research Unit.

However, the role of excessive moisture is far from clear. Supplementary experiments showed that maintaining compost and casing at high moisture levels increased nematode populations but did not affect yield. Perhaps in some cases, as we noted in several experiments, extremely high nematode populations at the end of harvest cause a buildup of metabolic by-products which inhibit mycelial growth or fruit body formation. The observation that high nematode populations at the beginning of crop production were associated with increases in total yield might be explained by nematodes transmitting certain *Pseudomonas* bacteria, theorized to be essential in pinhead formation. Obviously a complex relationship exists in this dynamic ecosystem and much more work will be required for a better understanding of the interaction mechanisms.

In practice, high saprophagous nematode populations can be avoided through proper conditioning of the compost, using naturally nematode-free or pasteurized casing material, and maintaining correct environmental conditions and a generally high standard of sanitary and cultural practices. Carbofuran offers promise in lowering nematode levels when prevention fails, but does not guarantee any yield increase. None of the nematicides tested are registered for use in mushroom production. Residue studies for carbofuran are still in progress. ■

SPICE CROPS: PRODUCTION POTENTIAL IN THE PRAIRIES

M. D. STAUFFER and
B. B. CHUBEY

Dans le cadre du programme d'importation de nouvelles cultures, la station de recherches de Morden a identifié des épices dont la culture semble prometteuse dans les Prairies. Les renseignements relatifs à la production de la plupart d'entre elles sont toutefois presque inexistants.

Until recently, a chicken in every pot was essentially the same for everyone; now it's coq au vin, chicken cacciatore, and so forth. Increasing interest in ethnic cookery in Canada has resulted from improved communications and greater mobility of people in the post-war era. It's not surprising then that use of spices has increased. At the same time, the spice industry has adopted stricter quality requirements, new processing techniques and improved spice formulations (e.g., curry powder, herb seasoning, barbeque spice). Since Canada imported over $20 million worth of spices in 1978, including the major spices such as pepper at $6.7 million and pimento at $4.5 million, it was considered that domestic production potential should be determined.

Commercial spice crop production, except for mustard, is generally considered to be exotic and is largely unknown to Canadian agriculture. With the new crops program at the Morden Research Station, high-potential spice crops have been identified, but production information on many of them is almost nonexistent. Among those identified as being agronomically suited are the seed crops coriander, caraway, dill, fennel, poppy, and fenugreek; the essential oil crops dill, monarda, peppermint, and sweet basil; and the herbs sage, summer savory, sweet basil, oregano, garlic, and chives. Research has identified variability within a crop which may allow selection of types suited to the southern Prairie environment. Currently, our investigations are aimed at establishing the production requirements as they influence yield and quality. As shown in Table 1, the spices with high potential are acceptable to the spice industry.

The Umbelliferae, or carrot, family is the forerunner in developing spice-crop production, initially with dill and subsequently with caraway, coriander, and fennel. Dill is grown on approximately 320 ha in southern Manitoba, the majority of it processed for the essential oil of dill and the remainder for seed. Caraway production is approximately 100 ha annually, whereas the latter has been of a pilot scale size. Coriander production ranges between 200 and 300 ha. Most of the coriander grown is the larger-seeded, lower-oil Moroccan type, but some of the Bulgarian/Rumanian type is also produced. Consistent high yields and quality have not been achieved, although maturity (85 days) falls well within the growing season. Planting and harvesting guidelines are only general; and research is underway to define the basic production requirements.

We found method of seeding to have significant effects on yield of coriander (Table 2). Seeding at 15 kg/ha, higher yields were obtained when planted with a press drill than a disc drill. More plants emerged with greater uniformity, probably the result of better contact of the seed and soil. Depth of planting also affected yield. The 4 cm depth and

Dr. Stauffer and Dr. Chubey are research scientists at Agriculture Canada's Morden, Man., Research Station.

press-drill combination was best for achieving early, vigorous emergence. Uniform emergence contributes to higher yield, reduces harvesting difficulties, minimizes yield loss, and retains seed quality.

Coriander seed grown in tests at Morden was evaluated as commercially acceptable (Table 1). The seeds were larger in size and weaker in aroma than the standards. Variability in size, aroma, and volatile oil content among lines has been identified.

Fennel, which has a characteristic liquorice taste, is not as well adapted to southern Manitoba as the other spices of the Umbelliferae tested. Earlier maturing lines have not been available for testing although it is known that early planting increases yield. Our experience is that delaying seeding from early to late May reduced yields from 1800 to 550 kg/ha. Quality was not reduced by delaying seeding and the fennel was rated typical in color and flavor, oil content being 1.2% (Table 1).

Among the herbs evaluated, sweet basil, sage and summer savory have the best potential. Sweet basil, however, is best documented. Dried-leaf (free-of-stem) yields increased as date of seeding was delayed until late, rather than early, May. Higher mean temperatures increase yields, but allow only one cutting/year, whereas with early planting and irrigation two cuts/season are possible. Quality and yield are best at early flowering, but since sweet basil is relatively photoperiodic insensitive, staggered seeding dates make sequential harvesting possible.

Based on color, purity and volatile oil content, Canadian-grown sweet basil is commercially acceptable (Table 1). However, agronomic production is only one aspect; another is preparation of a marketable product. Techniques to 1) remove debris, adhering soil, etc., 2) cure leaves to maintain color, aroma, and flavor, and 3) separate leaf tissue from the stem are costly but critical to producing a marketable product.

Seed and herb spice crops have established markets, so production in Canada depends upon quality and economic feasibility. A native species, monarda, can be grown successfully. The essential oil of monarda, however, is totally new and no definite market has been identified. Geraniol is a widely-used essential oil, but the availability of low-priced synthetic geraniol makes market acceptance of high geraniol monarda oil difficult. The plant contains 0.7% volatile oil, of which more than 90% is geraniol. By controlling

TABLE 1. EVALUATION OF CANADIAN-GROWN SPICES ASSESSED BY THE SPICE INDUSTRY.

Spice Crop	Overall Rating	Colour	Aroma	Volatile Oils (%)	Comments
Coriander	Accept.	Typical	Typical but weak	0.55	size larger than normal.
Fennel	Accept.†	Typical	Typical	1 20	greener than Indian.
Dill (seed)	Accept.	Typical	Typical	2.87	size slightly larger than normal.
Summer Savory	Accept.	Typical	Menthol strong	2.25	fairly high total ash.
Sage	Accept.	darker than normal	Menthol strong	2.01	fairly high total ash.
Sweet Basil	Accept.	V. dark green	V. good minty	0 40	very good, better than standard.

†Rejected by one company for low volatile oil content; others rated acceptable.

TABLE 2. CORIANDER YIELDS AND UNIFORMITY OF PLANT EMERGENCE AS INFLUENCED BY TYPE OF SEED DRILL AND PLANTING DEPTH.

Drill type	Planting depth (cm)	Plants/m of row	Early emergence (% of total)	Yield (kg/ha)
Disc	2	21.6	61.9	837
	4	22.8	90.7	1592
	6	25 1	97.5	1941
	Mean	23 2	83 4	1466
Press	2	39 9	78.1	1471
	4	39 5	100.0	2220
	6	35 0	96.1	1898
	Mean	38.1	91.4	1863

rust and providing supplemental water, current oil yields of 50-70 kg/ha could be greatly increased.

Much of the experience gained in the dill research is useful in researching and developing the potential of other spice crops. Apart from the direct experience, such as weed control, the benefit of having access to and co-operation with the spice industry helps progress. In some cases, advances were made because commercial evaluations were possible.

Only recently have some cultural practices been developed. Canadian agriculture can apply the technological requirements needed for sustained production of high-quality spices. ■

COPPER AVAILABILITY AND MANAGEMENT IN ORGANIC SOILS

H. A. HAMILTON

La faible teneur en cuivre est un problème fréquent dans les sols organiques. Toutefois, ce n'est pas une question d'assimilabilité car celle-ci est indépendante du dégré d'acidité dans l'écart de pH de 3.5 à 7 qui caractérise la plupart des sols organiques. Il reste à établir quelle quantité de cuivre il faut apporter au sol et s'il faut le faire en une seule grosse application ou en plusieurs fractions.

Organic soils occur more widely than we normally envisage. They are found under varying climatic conditions ranging from the tropics to the coldest northerly climes.

Dr. Hamilton is Head of Chemistry and Management of Organic Soils at Agriculture Canada's Research Station, St-Jean, Que.

In general, a problem of organic soils is their low copper content. In light of information we now have, this might not be as serious as it first appears.

For crops to receive the chemicals necessary for their proper development, the elements must be present in sufficient quantity in the soil. Other soil conditions must ensure that the elements will be taken up by the plant. Among the important conditions are soil pH, the degree of binding or bonding between the soil complex and elements, and the degree of decomposition of the soil.

In most organic soils, the major problem is that copper is found in very low quantities; therefore, one might expect virgin soils to be responsive to copper fertilization. Once copper has been added to these soils, availability in most instances is not a problem. The importance of pH in organic soils takes precedence over copper content. An undesirable pH, while not affecting

Soil pH	Farnham	Lefort	Dennigan	Ste-Clotilde
		(Carrot leaves) μ gm Cu/pot		
5.0	193	134	—	—
5.5	193	146	—	—
5.8	—	—	—	177
6.0	218	132	—	173
6.1	—	—	143	—
6.5	202	125	149	170

the uptake of copper, can seriously depress crop yield. In the pH range (5.0-6.5) found suitable for most vegetable crops, the availability of copper is independent of pH. This is obvious in the accompanying table for four soils in southwestern Quebec that were cropped to carrot.

The question of how much copper can be added to deficient virgin soils is yet to be resolved. We know that substantial quantities, several times in excess of what is needed for a single crop year, may be added without deleterious effects on a crop. We know that copper bonding increases with the degree of decomposition of organic soils. We also know that copper does not move readily in organic soils. This is evidenced by laboratory studies as well as by the fact that extremely low amounts have been found in drainage waters emanating from organic-soil areas. Environmental pollution caused by excessively high rates of copper does not appear likely.

The economics of a single, large application with availability for several years, or frequent applications annually, has yet to be determined precisely.

It should be emphasized that while organic soils behave in the manner indicated, this is not the situation for mineral soils. ■

ECHOES FROM THE FIELD AND LAB

ECHOS DES LABOS ET D'AILLEURS

LIVESTOCK METRICATION Livestock producers, dealers and auction operators have set January 1, 1980 as the date they will convert to metric measurement.

Livestock industry representatives reached agreement on the conversion date at a meeting held in Winnipeg in early January.

The meeting was called by the Metric Commission's Livestock Metric Co-Ordinating Committee — chaired by Charles Gracey, manager of the Canadian Cattlemen's Association.

Many aspects of livestock metrication have already been worked out by the government-industry committee.

There is agreement on the weight breakdowns to be used in trading The tentative weight ranges are reported in the January 4, 1979 issue of Canada Livestock and Meat Trade Report.

Grading regulations for beef, hogs and sheep now are being rewritten to a metric base, in conjunction with producer groups and the Meat Packers Council of Canada.

The beef Record of Performance (R.O.P.) programs will convert to metric on January 1, 1980 — swine and sheep R.O.P. are already measured in metric units. Agriculture Canada reports on U.S. livestock production and prices will also be converted to metric units.

KNAPWEED THREAT IN WEST Two weeds accidentally introduced into Canada pose a major threat to rangeland in the West if they go unchecked.

Diffuse and spotted knapweed, first discovered in North America around the turn of the century, now are firmly established in British Columbia and threatening to move into the dryland prairies.

That warning is given by Dr. Peter Harris, an Agriculture Canada biological control specialist at the Regina, Sask., Research Station. He says both weeds have low forage value and tend to displace more useful browsing plants.

Already the weeds have infested about 30,000 hectares in British Columbia. Recently small patches of diffuse knapweed have been spotted in Alberta. A total of 9 8 million hectares of prairie rangeland could be threatened by these troublesome weeds Ranchers who find dense knapweed stands are advised to consider chemical control and reseeding.

GYPSY MOTH OUTBREAK Several methods of controlling gypsy moth infestations in Vancouver's Kitsilano area are being investigated by Agriculture Canada's plant quarantine division in Vancouver.

Effective control methods include spraying techniques, egg mass removal, larval trapping and moth trapping using sex lures.

If uncontrolled, the gypsy moth could become a severe problem in the area's home gardens, parks, nurseries and forests, according to John Gold, district director of the plant quarentine division. If left unchecked, the moth population could spread to other parts of the province.

Considered the worst defoliator of deciduous trees and ornamentals in North America, this moth has caused quarentine of forest products in Eastern Canada.

Gold said that quarentine could become necessary also in the Vancouver area. He said that home owners may have to spray every year to protect trees and ornamentals if the Vancouver problem worsens.

Gold said that alternate control methods are being pursued and public information meetings are being planned for the Kitsilano area.

CONTAINER GARDENING Home-grown fruits and and vegetables are no longer the preserve of house owners. Apartment dwellers and town house occupants can grow their own fresh produce through container gardening.

Containers can range from window boxes to discarded children's sand pails or wading pools or even a plastic bag of soil. Balconies, patios and rooftops can be used to place the containers. But a handy supply of water is a must.

Agriculture Canada specialists recommend commercially prepared soil mixes because they are easy to use. If you mix your own, keep the mixture light to reduce weight and give good drainage.

The specialists also recommend that anyone starting out for the first time should begin on a small scale, both in size of the garden and investment. For the first year the garden should be large enough to keep up your interest, but small enough to be learned from and improved on the next year.

Easily grown vegetables include beans, cabbage, carrots, cucumber, lettuce, peas, radishes, spinach, tomatoes and zucchini.

An A-frame may be the answer to get a good selection with little space.

Containers need not be fancy. They may be an old tire . . . . or even a bag of soil.

If space is a problem you can grow fresh produce through container gardening.

SEEDS FOR THE FUTURE In the year 35,000 A.D., plant scientists may be using barley seeds placed in cold storage now, thanks to a plant gene pool developed by Agriculture Canada in Ottawa. The pool was set up to halt the loss of genetic stock used in breeding programs.

The seed stocks are kept in special facilities in Ottawa. Some units store seed at 4°C and 20 percent relative humidity. These seeds should be good for about 15 to 20 years. Other new units store seeds in moisture proof envelopes at −20°C. At this temperature, wheat can be kept for about 400 years and it is estimated barley up to 33,500 years.

At present, the pool contains varieties of barley, tomatoes, alfalfa, wheat and oats. Other crops will soon be added.

NEW BLANCHER TO BE TESTED A new blancher that retains more vitamins in vegetables, saves energy and creates less effluent is to be tested commercially this summer. The tests will be carried out as part of the federal government's Co-operative Projects with Industry Program.

The blancher was designed by Agriculture Canada's Kentville N.S., Research Station in conjunction with the department's Engineering and Statistical Research Institute in Ottawa. It uses steam instead of boiling water to blanch vegetables before freezing.

Results of more than two years of tests show steam-blanched vegetables have flavor, color, texture and taste equal to, or better than water-blanched products. The new blancher is also considerably more energy efficient than a hot water counterpart or conventional steam blancher.

STARTING A FARM IN CANADA This is a new publication available from Information Service, Agriculture Canada, which presents a thumbnail sketch of farming in Canada for those who seek a comprehensive overview of the subject. In particular, it is aimed at people who are considering taking up farming on a part-time basis or as a full-time business.

Information in the publication is set out in the following sections:

1. "Type of Farming" The initial section outlines and explains the types of farming practiced in Canada, the range of enterprises that might be undertaken, and the scope of capital, management, and labor required by the enterprises selected.
2. "Some Economic Aspects of Farming" This section comments on the amount of capital likely to be needed and explains the various lending organizations that provide farmers with the necessary capital. It also deals with several economic considerations of farming, including income.
3. "Choosing a Type and Location of Farm" The importance of exercising care in choosing the type and location of farm is emphasized. A review of considerations is provided that should be studied and assessed before making a decision on where to locate and what type of farming to select.
4. "Advisory Services and Sources of Information" This section outlines the abundant sources of advice and information that are available to the farming public.
5. "Appendices" Some cost of production illustrations are presented.

TWO MILLIMETRES OF TROUBLE An insect that is only about two millimetres long is a troublesome pest on mammals — including man. Fleas may infest homes, bird cages and poultry houses. Some kinds of fleas transmit diseases to man. Also, cat and dog fleas are sometimes intermediate hosts for the dog tape worm which may infest man.

But, Agriculture Canada specialists say these tiny pests can be controlled. One of the best methods is to keep your house clean. Regularly clean pets' bedding and places where they sleep. Also clean the basement if it is used by household pets.

There are flea powders, shampoos, collars and tags for pets. And to stop treated animals from being reinfested, buildings should be treated at the same time as animals. Because nearly all insecticides are poisonous, the specialists emphasize that instructions and cautions on the labels must be followed.

MORE STATISTICS ON EXOTIC CROSS-BREEDS Eleven years of detailed research by Agriculture Canada scientists has produced more performance data on exotic cattle breeds.

Th work was carried out at the federal department's research stations at Brandon, Man., and Lethbridge and Lacombe, Alberta.

The latest set of statistics from Agriculture Canada researchers covers an extensive cross-breeding project involving Charolais, Limousin, Simmental and Chianina exotic breeds and Hereford, Angus and Shorthorn domestic animals.

Research will be continued to give cattlemen a completed picture of expected performance under Canadian conditions.

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